



## Combustion Analysis on HCCI Engine By Using Blended Fuel With Varying Injection Timing Of PCCI

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**Abstract:** There are two sorts of inside burning motors in particular the sparkle ignition (SI) and the pressure ignition (CI). Petrol and diesel are at present rule powers for SI and CI motors. These energizes are very nearly getting wiped out. The fuel oxidation process in the motor produces valuable force, as well as a lot of poison outflows including carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), unburned hydrocarbon (HC), nitrogen oxides (NO<sub>x</sub>), and particulate matter (PM).

HCCI (Homogeneous Charge Compression Ignition) is a clean and efficient combustion process. In this project work an attempt is made to experimentally analyze the combustion characteristics of the HCCI compression process in a PCCI (Premixed Charge Compression Ignition) mode assisted with pilot injection (PI). Pilot Injector is an injector which is placed at inlet manifold. Here we used B30 (700 ml of diesel+ 300 ml of bio diesel) as a secondary fuel and diesel as primary fuel. By changing the injection timing of the PCCI mode at 20°, 40°, 60° of the crank angle we have done an experiment and analyzed exhaust gases compared to conventional CI engine and also seen efficiencies of both HCCI and CI engines

### 1. INTRODUCTION

In today's world, the Internal Combustion (IC) engine is the key to the entire transportation sector. Without the transportation performed by the millions of vehicles on road and at sea, we would not have reached modern living standards. The Spark Ignition (SI) and the Compression Ignition (CI) are the two sorts of IC motors. Petrol and diesel are at present the key powers utilized for SI and CI motors individually. These energizes are nearly getting terminated and amid burning these fills discharge a generous measure of poisons into the air and make environment related issues. The IC engine is known as one of the major

sources of air pollutants in the environment. The fuel oxidation process in the motor produces valuable force, as well as a lot of poison emanations including Carbon Dioxide (CO<sub>2</sub>), Carbon Monoxide (CO), Unburned Hydrocarbon (HC), Nitrogen Oxides (NO<sub>x</sub>), and Particulate Matter (PM). Diminishing the fumes emanations and expanding the mileage of IC motors are of worldwide significance.

CO<sub>2</sub> is mainly responsible for the global warming issue, as it creates a reflective layer in the atmosphere that reflects heat from the earth back to the earth's surface, increasing the earth's average temperature over time. CO is a very dangerous substance since it reduces the oxygen-carrying capacity of the blood stream. At low concentrations, CO inhalation can cause dizziness and nausea, while at higher concentrations, it can be deadly (Shreet al 1998). Unburned hydrocarbon emission, a result of an incomplete combustion process, is a common source of respiratory problems. Particulate emissions or soot also cause some respiratory problems. Both unburned hydrocarbon and soot emissions have been linked to diseases like cancer (Shreet al 1998). The high flame temperature generated during the combustion process is responsible for NO<sub>x</sub> formation which causes various health problems and also contributes to acid rain and global warming issues. The development of efficient IC engines with ultra low emissions is necessitated by strict regulations on exhaust gas composition and fuel economy. Increasing concern over the potential global warming effects of major greenhouse gases from current fossil fuels, coupled with a rapidly growing vehicle fleet around the world has intensified the uptake of alternative fuels and become an important area of research (Yap et al 2005).

## 2. EXPERIMENTAL SETUP

### 2.1 Introduction

The engine experiments are conducted to validate the application of the analysis and to implement strategies for HCCI start ability and control. In the present research work, an agricultural water-cooled single cylinder engine which is very well-suited for HCCI operation has been used. Experiments are conducted for different load conditions and different fuel combinations. Based on the results obtained from the experiments, the performance and emission graphs are plotted. The detailed description of the experimental setup, properties of the samples and experimental procedures are discussed in this chapter.

### 2.2 Experimental Apparatus

The research engine was based on a single cylinder, Direct Injection (DI), and four-stroke cycle diesel engine with 0.553 lit of piston displacement (agricultural type water-cooled). The specifications and dimensions of the test engine are listed in Table 2.1. The experimental apparatus consists of the primary fuel supply system, the exhaust gas analyzer system, the thermostat air temperature control system and the pilot injection system. A gravity feed fuel system with an efficient paper element filter, and force feed lubrication is also used. Large end bearings and camshaft bush, suitable for run-through or thermosyphon cooling are also provided in the present system.

**Table 2.1 Specifications of the experimental setup**

S. No.	Details	Specifications
1.	Number of cylinders	One
2.	Bore x Stroke	87.5 x 110 mm
3.	Cubic Capacity	0.553 lit
4.	Compression Ratio	17.5
5.	Rated Output	3.7 kW(5.0hp) at 1500rpm

6.	SFC at rated hp/1500rpm	245 g/kWh (180 g/bhp-hr)
7.	Lube Oil consumption	1.0 % of SFC max.
8.	Lube Oil Sump Capacity	3.3 lit
9.	Fuel Tank Capacity	6.5 lit
10.	Engine Weight (dry) without flywheel	114 kg
11.	Weight of flywheel	33 kg
12.	Rotation while looking at flywheel	Clock-wise
13.	Power take-off	Flywheel end

Figure 2.1 shows the schematic diagram of the experimental apparatus used for the present research work. The pilot injection system is attached to the air manifold to supply the secondary fuel in the HCCI mode. The pilot injection system consists of a pilot injection valve and fuel measurement system. The heating and thermostat arrangements are also attached to the air manifold to preheat and measure the temperature of the air respectively. Diesel, petrol and bio diesel are used as fuels in this research work.

### 2.3 SAMPLE FUELS

Diesel, petrol and bio diesel are used for this research work as sample fuels. The specifications of these samples are identified by standard test methods. The properties of diesel, petrol and bio-diesel are listed in Table 2.2.

**Table 2.2 Properties of Diesel**

Properties	Diesel
Density 15 °C Kg/m <sup>3</sup>	830
Octane Number	-
Cetane Number	51
Kinematic Viscosity at 40°C (m <sup>2</sup> /s)	1.3
Flash point °C	55
Specific gravity	0.85
Auto-ignition Temperature (°C)	263
Molecular Weight	200

## 2.4 EXPERIMENTALPROCEDURE

In this research work, experiments are conducted in the conventional and HCCI mode with all the fuel samples. Initially, the engine is operated in the conventional mode using diesel and bio-diesel as a primary fuel; there is no secondary fuel supply. The efficiency, fuel consumption, exhaust gas temperature and emissions are measured under different load conditions. The different percentages of varying loads are: 0%, 25%, 50%, 75% and 100%.

In the HCCI mode, the pilot injector is used to supply secondary fuel to the combustion chamber to get the Premixed Charged Combustion Ignition (PCCI).The pilot injector works by means of the signal from the rocker ram. The opening and closing of the pilot injector for supplying the secondary fuel depends upon the position of the rocker arm, which depends upon the position of the piston inside the combustion chamber. The air is heated to a temperature of 80°C before it is sent into the combustion chamber. The primary fuel is supplied to the combustion chamber without heating. In the case of the secondary fuel supply, the fuel is heated before entering the inlet manifold. The heating is done by an electrical heating arrangement. The secondary fuel is supplied into the combustion chamber in the suction stroke. This will create PCCI during the compression stroke and help to ignite the fuel which is supplied by primary injection and get the HCCI. This HCCI helps to get

complete combustion and uniform low temperature throughout the combustion chamber.

The exhaust gas is analyzed by means of a five-gas analyzer to measure the HC, CO, CO<sub>2</sub>, NO<sub>x</sub> and O<sub>2</sub> present in the exhaust gas. The exhaust gas temperature and smoke contents are measured by means of the thermocouple and smoke meter respectively. The primary fuel, secondary fuel, and air quantity are measured before they enter the combustion chamber.

### 2.4.1 DIESEL AND B30 PCCI-DI Combustion

In this mode of experiment, both diesel and B30 (700ml diesel +300 ml biodiesel) are used as primary and secondary fuel respectively. The diesel is injected into the cylinder through the primary injector; the injected diesel is compressed to increase the pressure. The pilot injector supplied the B30 to the combustion chamber before the actual injection of the diesel into the combustion chamber through the primary injection port. The emissions and fuel consumptions are measured in this mode.The experiment is conducted at different injection timings of pilot injector i.e.,at 20°,40°,60° of the crank angle.

## 2.5 EXHAUST GAS ANALYSER

The use of a four or five gas exhaust analyzer can be helpful in troubleshooting both emissions and drive ability concerns. Presently, shop grade analyzers are capable of measuring from as few as two exhaust gases, HC and CO, to as many as five. The five gases measured by the latest technology exhaust analyzers are: HC, CO, CO<sub>2</sub>, O<sub>2</sub> and NO<sub>x</sub>. The photographic view of the exhaust gas analyzer used is shown in Fig3.5.



**Figure. Photographic view of the exhaust gas analyzer showing a sample result**

### 3. RESULTS AND DISCUSSION

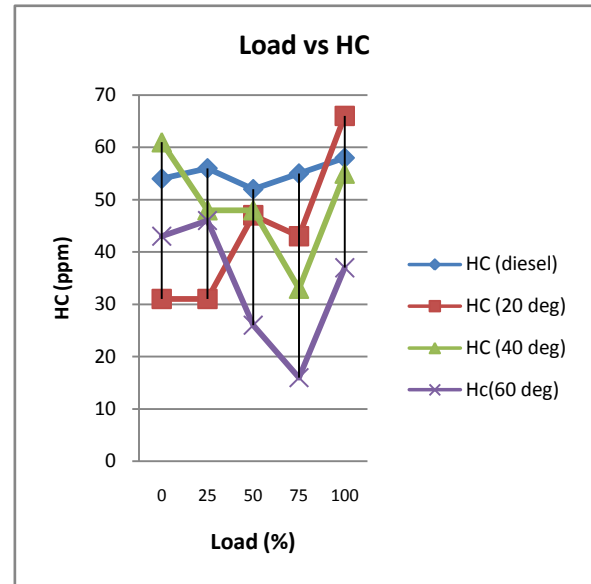
#### 3.1 INTRODUCTION

Several experiments have been conducted on the present experimental setup in order to assess the performance of the developed HCCI system. The effects of the load on parameters such as exhaust gas temperature, hydro carbon in exhaust, NO<sub>x</sub> emission in exhaust gas, specific fuel consumption, brake thermal efficiency, carbon dioxide, and carbon monoxide emission are discussed in this chapter. A detailed description of the graphs comparing: the conventional and HCCI methods, hydrocarbon emissions in the conventional and HCCI methods, hydrocarbon emissions from different injection timings in the HCCI mode, NO<sub>x</sub> emissions in the conventional and HCCI methods, NO<sub>x</sub> emissions from different injection timings in the HCCI mode, NO<sub>x</sub> emissions with different loads in different HCCI modes, specific fuel consumption between the conventional and HCCI methods, specific fuel consumption between different injection timings in the HCCI mode, specific fuel consumption with different loads in different HCCI modes, brake thermal efficiency between the conventional and HCCI methods, brake thermal efficiency with different injection timings in HCCI modes, brake thermal efficiency with different load in different HCCI modes, CO<sub>2</sub> emission in the conventional and HCCI methods, CO<sub>2</sub> emission between different injection timings in the HCCI mode, CO<sub>2</sub> emissions with different load in different HCCI modes, CO emission in the conventional and HCCI methods, CO emission between different injection timings in the HCCI mode, CO emissions with different load in different HCCI modes

#### 3.2 EFFECT OF LOAD ON HYDRO CARBON IN EXHAUST GAS

The hydrocarbon emission from all the modes is observed with different load conditions. Figure 3.5 represents the variation of HC emission with the increase of load from 0% to 100%. The study found that the HC emissions from the conventional diesel mode is higher than that the injection timing at 60° of the crank angle and at 20° injection timing HC emission increase at full load and at 40° injection timing, HC emission increase at no load conditions and decrease at remaining loads. The

HC emission increased with the increase of load for conventional mode and decreased with the increase the load of HCCI methods.



**Fig.3.1**

**Variation of different loads with different HC emissions**

LOAD	DIESEL	20 <sup>0</sup>	40 <sup>0</sup>	60 <sup>0</sup>
0	54	31	61	43
25	56	31	48	46
50	52	47	48	26
75	55	43	33	16
100	58	66	55	37

**Table.3.1**

#### 3.3 EFFECT OF LOAD ON NO<sub>x</sub> EMISSIONS IN EXHAUST GAS

The effect of load on the NO<sub>x</sub> emission in the conventional and HCCI modes. The study found that NO<sub>x</sub> emission from diesel in the conventional engine is lower than the different injection timings of the HCCI engine at 0 to 100 % load conditions.

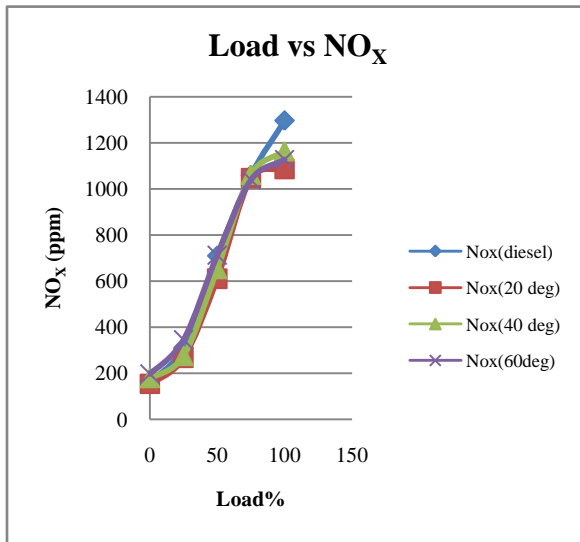


Fig.3.2

Variation of different loads with different NO<sub>x</sub> emissions

LOAD	DIESEL	20 <sup>0</sup>	40 <sup>0</sup>	60 <sup>0</sup>
0	165	155	180	197
25	311	265	276	345
50	709	611	653	712
75	1059	1047	1062	1083
100	1296	1086	1164	1127

Table.3.2

### 3.4 EFFECT OF LOAD ON CARBONMONOXIDE

The effect of load on the CO emission in the conventional and HCCI modes. The study found that CO emission from diesel in the conventional engine is lower than the different injection timings of the HCCI engine at 0 to 100 % load conditions.

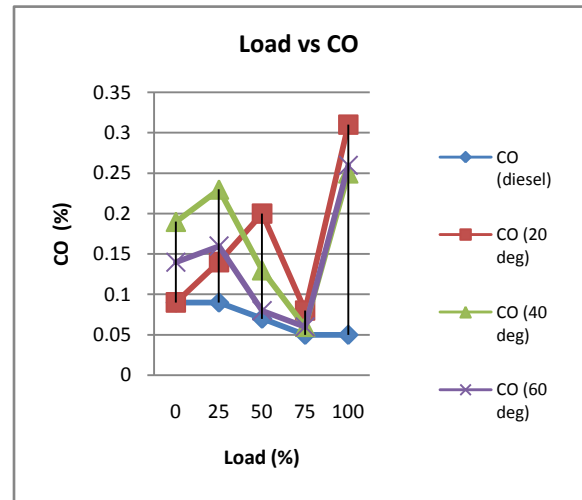


Fig.3.3

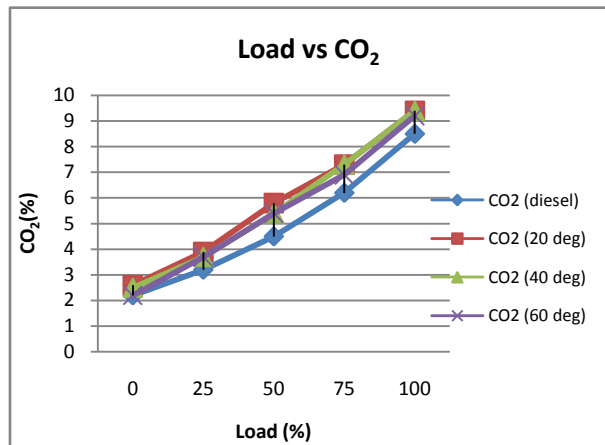
Variation of different loads with different CO emissions

LOAD	DIESEL	20 <sup>0</sup>	40 <sup>0</sup>	60 <sup>0</sup>
0	0.09	0.09	0.19	0.14
25	0.09	0.14	0.23	0.16
50	0.07	0.2	0.13	0.08
75	0.05	0.08	0.06	0.06
100	0.05	0.31	0.25	0.26

Table.3.3

### 3.5 EFFECT OF LOAD ON CARBONDIOXIDE

The effect of load on the CO<sub>2</sub> emission in the conventional and HCCI modes. The study found that CO<sub>2</sub> emission from diesel in the conventional engine is lower than the different injection timings of the HCCI engine at 0 to 100 % load.



**Fig.3.4**  
Variation of different loads with different  
CO<sub>2</sub> emissions

LOAD	DIESEL	20 <sup>0</sup>	40 <sup>0</sup>	60 <sup>0</sup>
0	2.2	2.6	2.5	2.2
25	3.2	3.9	3.7	3.7
50	4.5	5.8	5.4	5.4
75	6.2	7.3	7.3	6.9
100	8.5	9.4	9.4	9.20

**Table.3.4**

#### 4.CONCLUSION

##### 4.1 FINDINGS FROM THE RESEARCH

The research has been comprehensive keeping in mind the current and future needs of HCCI. The result of this exhaustive research has brought out the application of bio-diesel to the emerging needs of HCCI combustion. The salient details of the research findings are as follows:

1. Four different modes such as the diesel and B30 PCCI-DI Combustion incorporated in the proposed HCCI system.
2. Various parameters such as exhaust gas temperature, HC, NO<sub>x</sub>, CO, SFC, BTE, and CO<sub>2</sub> are measured and analyzed.
3. A MRU DELTA 1600L five gas analyzer is used for conducting the experiment.
4. The PCCI approach is adopted to conduct the HCCI experiment.
5. The pilot Injection(PI) system is used.

##### 4.2 LIMITATIONS

Research and development in this area is cumbersome and takes a lot of time and large-scale effort. The limitations of the present study are that only three combinations modes are tried. Another limitation of this study is that friction losses and charge leakage through the cylinder-piston gap are not considered; it may constrain the engine size, and impose minimum engine speed limits.

##### 4.3 SCOPE FOR FUTURE RESEARCH

The present investigation has greatly expanded our understanding of HCCI, the controlling mechanisms, and HCCI engine operation strategies. However, the present research can be extended to various other alternative fuels such as CNG, LPG, biogas, and chemfuels, and the reduction of emission can be studied and analyzed. The present system can be slightly modified to design low NO<sub>x</sub>, low particulate reciprocating engines with improved diesel efficiency. Research and development is needed to develop methods to slow the rate of combustion in HCCI engines at high engine loads, to prevent excessive noise and engine damage. Similar research can also be done to develop concepts to overcome the challenge of ignition in cold HCCI engines without compromising the warm engine performance. The present system can be adopted to develop intake and exhaust manifold designs for multi-cylinder engines to overcome the challenge of maintaining strict uniformity of the inlet and exhaust flows of each cylinder to assure smooth engine operation.

##### 4.4 CONCLUSION

This research work aims to reduce emission in HCCI engines in the PCCI mode with different injection timings. The following conclusions are drawn:

- The study found that the HC emissions are decreases in HCCI modes when compared with conventional engine.
- ❖ At HCCI engine 20<sup>0</sup> injection timing HC emissions are decreases than conventional mode except at full load condition.
- ❖ At HCCI engine 40<sup>0</sup> injection timing HC emissions are decreases than conventional mode except at zero load condition.
- ❖ At HCCI engine 20<sup>0</sup> injection timing HC emissions are decreases than conventional mode except at all loads.



- The study found that the specific fuel consumption decreased with the increase in load for all modes of operations. The lowest specific fuel consumption is observed blend as primary fuel and diesel as secondary fuel in HCCI mode at 600 injection timing except at full load than conventional engine.
- The study found that the Brake thermal efficiency increases in HCCI mode at 20°, 40°, 60° injection timing than conventional mode except at full load.
- The study observed that the CO<sub>2</sub> emission from the HCCI mode is higher than conventional mode. Among all injection timings i.e., 20°, 40°, 60° in HCCI mode. We get lower CO<sub>2</sub> emissions at 20° injection time.
- The study observed that the mechanical efficiency is higher in HCCI mode compared to conventional engine.
- The study found that the NO<sub>x</sub> emissions increases with the increase in load for both conventional engine and HCCI engine at 20°, 40°, 60° injection timings. But in the case of HCCI engine at 20°, 40°, 60° injection timings NO<sub>x</sub> decreases than the conventional engine at full load condition.
- NO<sub>x</sub>, HC emissions are decreased in HCCI mode compared to conventional engine.
  - Specific fuel consumption also decreases in HCCI engine when compared to conventional engine.
  - Brake thermal efficiency is increased in HCCI mode compared to conventional engine except at full load.
  - Mechanical efficiency is increased in HCCI mode compared to conventional engine.

Once properly introduced in the process, the proposed HCCI combustion system should improve performance and reduce the emission and consequently contribute to the efficiency profitability of the automobile industry.

## REFERENCES

[1] Ishibashi Y. and Asai M. (1998) 'A Low Pressure Pneumatic Direct Injection Two-Stroke Engine by Activated Radical Combustion Concept', SAE Paper 980757.

[2] Thring R.H. (1989) 'Homogeneous Charge Compression Ignition (HCCI) Engines', SAE Paper 892068.

[3] Stanglmaier R.H., Ryan T.W. and Souder J.S. (2001) 'HCCI Operation of a Dual-Fuel Natural Gas Engine for Improved Fuel Efficiency and Ultra-Low NO<sub>x</sub> Emissions at Low and Moderate Loads', SAE Paper 2001-01-1897.

[4] Christensen M., Johansson B. and Einewall P. (1997a) 'NO<sub>x</sub> emissions in HCCI operation depend on the fuel characteristic', SAE Tech Pap Ser No 972824.

[5] Christensen M., Johansson B. and Einewall P. (1997) 'Homogeneous Charge Compression Ignition (HCCI) Using Isooctane, Ethanol, and Natural Gas – A Comparison with Spark Ignition Operation', SAE Paper 972872.

[6] Dae Sik Kim (2006) 'Partial HCCI (homogeneous charge compression ignition) combustion as a control mechanism for HCCI combustion', Fuel, Vol. 85, pp. 695-704.

[7] Lei Shi, Yi Cui, Kangyao Deng, Haiyong Peng and Yuanyuan Chen (2006) 'Study of low emission homogeneous charge compression ignition (HCCI) engine using combined internal and external exhaust gas recirculation (EGR)', Energy, Vol. 31, pp. 2665-2676.

[8] Dae Sik Kim (2007) 'Combustion and emission characteristics of a partial homogeneous charge compression ignition engine when using two-stage injection', Combustion Science and Technology, Vol. 179, pp. 531-551.

[9] Francisco Payri (2009) 'Studied the amount of each hydrocarbon species', Atmospheric Environmental, Vol. 43, pp. 1273-1279.

[10] Myung Yoon Kim (2007) 'The effect of narrow fuel spray angle injection and dual injection strategy on the exhaust emissions of a common rail diesel engine was investigated', Fuel, Vol. 86, pp. 2871- 2880.